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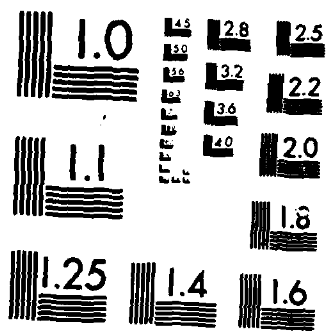

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United States General Accounting Office

GAO

Report to the Chairman, Committee on Science and Technology
House of Representatives

February 1986

UNIVERSITY FUNDING

Assessing Federal Funding Mechanisms for University Research

GAO/RCED-86-75

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-221714

FEB 7 1986

The Honorable Don Fuqua
Chairman, Committee on Science and Technology
House of Representatives

Dear Mr. Chairman:

As requested in your November 2, 1984, letter, we have assessed the impact of funding mechanisms on the productivity and performance of university research. This report discusses the role particular funding mechanisms played in helping universities improve program quality and different effects individual project grants and center grants had on the performance of research.

We are sending copies of this report to appropriate committees of both Houses, the Director of the Office of Management and Budget, the Director of the Office of Science and Technology Policy, and the chief officials of the following federal agencies: the Departments of Agriculture, Energy, and Defense; the National Aeronautics and Space Administration; the National Institutes of Health; and the National Science Foundation. We are also making copies available to interested organizations and individuals.

Sincerely,

J. Dexter Peach
Director

Executive Summary

Over 60 percent of university research funding comes from federal agencies. This research is a key element in the United States' international competitiveness and technology advancement. Other sources for research funding include industry, foundations, and state governments.

Approximately 71 percent of the federal research funds are provided through one funding mechanism or category of federal financial support for scientific research—individual project grants. Some scientists and policymakers have questioned the consequences of such heavy reliance on individual project grants. For example, does this mechanism discourage the performance of innovative, high-risk, and interdisciplinary research?

In response to the House Committee on Science and Technology's request that GAO assess the effects of different funding mechanisms on the productivity and performance of research, GAO looked at:

- Whether particular funding mechanisms played a role in helping universities improve program quality.
- Whether two funding mechanisms—individual project grants and center grants—had different effects on the performance of research.

In addition, GAO is providing the Committee with a separate report that describes the funding mechanisms used by federal agencies to support university research and trends in the use of such mechanisms.

Background

GAO looked at five universities that, according to surveys of the scientific community carried out by two education and research organizations, had reputed improvement in program quality. GAO concentrated primarily on what funding and other strategies these universities used to improve the selected departments and how the departments were able to finance their program improvement initiatives.

Two mechanisms for federal funding of university research are individual project grants and center grants. Individual project grants support individual researchers who do specific research. Center grants, which account for 9 percent of grants awarded, support broad coherent research programs and include coverage of facilities, equipment, and scientific and administrative personnel.

GAO assessed the merits of the two funding mechanisms against four factors that have the potential to affect the performance of research:

- Coverage of resource requirements, which includes trained technicians, equipment, and laboratory space.
- Stability of financial and resource support, which reflects the continuity and duration of support.
- Type of research supported, which includes the influence of funding availability on the flexibility to pursue new and different areas of research.
- Administrative burden, which includes researchers' time spent preparing proposals, overseeing grants, and reviewing proposals by others.

Results in Brief

The particular funding mechanism for university research played a lesser role in helping universities improve program quality than their ability to obtain grant funds from such sources as the federal government, state government, industry, and the university itself.

Responses of scientists to GAO's questions on coverage of resource requirements and administrative burden showed that these factors were less affected by the particular funding mechanism than by the field of science. On the other hand, scientists working under center grants responded that they had more stability of financial and resource support and that they were more likely to perform the types of research defined as innovative, high risk, or interdisciplinary than scientists working under individual project grants.

GAO's Analysis

Improving Research Quality

At the five universities GAO visited that were reputed to have improved program quality, the common element in improvement was an explicit commitment from the university to improve quality through increases in internal and/or external funding and personnel changes. Initial funding was necessary for building quality, although it came from a variety of sources. Two of the universities received National Science Foundation science development grants in the late 1960's that enabled them to bring in high-quality junior and senior faculty. Another university received state appropriations that were used to hire new faculty and increase the number and quality of postdoctoral fellows. Another university used funds from industrial sponsors to implement its plan for program improvement. (See chapter 2.)

Performance of Research

Coverage of resource requirements differed by field of science rather than by the type of funding mechanism (individual project or center grant). Fields of science differ in their needs for such resources as technicians, equipment, and laboratory space. For example, mathematicians working on theories may work in isolation with few assistants and little or no equipment. In contrast, cell biologists may need a number of lab assistants, and space scientists may invest large amounts of capital in equipment.

Scientists' concerns about stability of resources and financial environment differed depending on their field of science rather than on the funding mechanism. For example, award duration affects stability because award periods do not always match the actual time needed to perform research. Biochemistry projects may take less time to complete than genetic manipulation experiments in agriculture, where scientists must allow a complete new generation of crops to grow before testing can take place.

Scientists working under center grants reported that they were more likely to perform types of research defined by the National Science Foundation as innovative, high risk, or interdisciplinary than scientists receiving individual project grants. For example, 25 out of 32 scientists with center grants said they proposed research into new areas as opposed to 14 out of 33 scientists receiving individual grants. Scientists working under center grants believed they had more stability and resources to conduct these types of research.

Administrative burden, as measured by the amount of time spent in preaward activities (applying for awards) and postaward activities (responding to award requirements and reviewing proposals), varied more by field of science and agency requirements than by type of mechanism. Defense agency award requirements include postgrant reporting, while civilian agency award requirements include more preaward reviews of proposed research. On the average, scientists in fields, such as artificial intelligence, that receive awards from defense agencies, reported they spent more time in postaward activities than in preaward activities. Scientists in fields, such as plant science, that receive awards from civilian agencies reported spending more time in preaward activities. (See chapter 3.)

Recommendations

GAO is making no recommendations.

Agency Comments

We did not request agency comments because our work was not carried out at any agencies and we do not have any adverse comments about any agencies or organizations. However, we requested comments on portions of the report from the five universities cited in chapter 2 as having improved program quality. Those comments are incorporated in this report.

Contents

Abbreviations

GAO	General Accounting Office
NIH	National Institutes of Health
NSF	National Science Foundation

Introduction

Since its inception in the late 1940's, the current U.S. system for scientific research has emphasized supporting individual scientists' research projects through national competition for awards. According to the National Academy of Sciences, the scientific community often associates the individual project award system with the success of U.S. basic research and views it as affording the greatest degree of opportunity for pursuit of meritorious ideas.

Despite the belief that the individual project mechanism is closely linked with U.S. success in basic research, the House Committee on Science and Technology has noted problems concerning the current funding system in which this award type predominates. This report, which was requested by the House Committee on Science and Technology, assesses the roles and impact of different kinds of support for university scientific research in different fields of science.

Among the problems with the current system noted by the Committee and others, such as the National Academy of Sciences, are:

- the increased volume of applications for research support that need to be reviewed;
- the tendency to fund traditional research ideas rather than innovative ones; and
- constraints in the provision of scientific research resources, such as equipment and personnel.

How the Current Funding System Supports Scientists

Scientific research in the universities depends heavily on the federal government. In fiscal year 1982 federal agencies provided 64 percent of the $7.3 billion spent at universities for research. The federal government supports university research through a variety of funding mechanisms. For purposes of this report, funding mechanisms are categories of federal-financial support for scientific research performed by U.S. universities; they can be divided into direct and indirect support.

Three funding mechanisms directly support research: the individual project mechanism, program support, and center support. Individual project awards are typically made to individual scientists for research that they have proposed in a discrete research area. This is by far the predominant mechanism, accounting for 71 percent of agency support. Program support provides support for more than one principal investigator in a broad coherent program of research, often multidisciplinary and long term. Center support provides funding for research projects

that are coordinated into a coherent program in a broad field of interest at a university. The center award is the only mechanism that provides funding both for research and for equipment, facilities, and an administrative unit in the university. A recent illustration of the use of this funding mechanism is the National Science Foundation's (NSF's) establishment of engineering research centers, designed to strengthen this field by providing a concentration of facilities, personnel, and equipment.

Three other funding mechanisms indirectly support research by providing funds for "infrastructure." These funding mechanisms are training, equipment and facilities support, and institutional support for a university.

Objectives, Scope, and Methodology

The House Committee on Science and Technology requested that GAO assess the relative merits of different funding mechanisms in terms of their effects on the type of research being supported, research performance and productivity, agency procurement administration, management and administration by the performing organization, and from the point of view of the individual scientist. As a result of a literature review, the advice of a panel of experts, and consultations with the Committee, we agreed to assess funding mechanisms as they are used by recipients in different fields of science at specific research organizations. Our objectives in this assessment were

- to determine whether particular funding mechanisms play a role in helping universities improve program quality as perceived by the scientific community and
- to examine whether two different types of funding mechanisms—individual project grants and center grants— had different impacts on the performance of research.

Because almost no empirically based literature exists on funding mechanisms and their effects on research organizations, we adopted an exploratory approach to identify those issues that warrant further attention from policymakers. We conducted case studies at 15 different university research organizations. We used two sets of case studies, one focusing on reputed improvement in program quality, and the other on research performance and the perspective of individual scientists.

The Committee originally had included research productivity among the factors it requested we review. However, we determined that we could

not precisely assess the effects of funding mechanisms on research quality and productivity because of current limitations in the techniques for measuring the outputs of research. Instead, in consultation with the Committee, we explored the linkages between the types of support flowing into research organizations and the reputed research quality of those programs.

We focused on how selected university departments were able to improve their research programs after the federal government had largely eliminated special financial assistance for program improvement in the early 1970's. We selected five universities that had successfully improved various departments over the past decade on the basis of two national surveys of U.S. research doctoral programs. The first ("A Rating of Graduate Programs") was conducted in 1969 by Kenneth D. Rouse and Charles J. Anderson for the American Council of Education, and the other ("An Assessment of Research Doctoral Programs in the United States") was conducted by the Conference Board of Associated Research Councils and published in 1982.

We used the following criteria to select the five universities after consulting with the study director of the 1982 survey.

- First, where did departments stand in terms of the 1982 survey's ranking of program quality improvement as based on responses from scientists in the same field around the country.
- Second, which departments showed the greatest change between 1969 and 1982 in program reputation, again based on scientists' assessments.

We visited the following universities and departments where we interviewed university administrators and faculty members and reviewed program improvement documentation and financial records. We looked at the role of funding mechanisms in the universities' program improvement strategies. Due to resource constraints, we focused on departments in one geographic region—the southeastern United States.

Table 1.1: Universities With Reputed Improvement in Program Quality

University	Department/School
Emory University	Department of Microbiology and Immunology
Georgia Institute of Technology	School of Chemical Engineering
University of Alabama in Birmingham	Department of Physiology and Biophysics
University of Texas at Austin	Department of Physics
University of Georgia	Department of Botany

To respond to the Committee's interest in the effects of different funding mechanisms on the performance of research, we designed our second set of case studies to explore further some of the problems cited with current federal support for university research. Time and resource constraints prevented us from assessing all six categories of funding mechanisms, but the approach we took still sheds light on issues endemic to all funding mechanisms. Our objective in this second set of cases was to examine whether two different types of funding mechanisms had different impacts on the performance of research. To meet this second objective, we studied two funding mechanisms, center funding and the individual project award mechanism, that together represent 80 percent of the federal dollars obligated for university research. We examined the impact of these two funding mechanisms by examining four factors related to the performance of research:

- coverage of research resource requirements, which includes trained technicians, equipment, and laboratory space;
- the stability of support, which reflects the continuity and duration of support;
- the type of research supported, which includes the influence of funding availability on the flexibility to pursue new and different areas of research; and
- administrative burden, which includes researchers' time spent preparing proposals, overseeing grants, and reviewing proposals by others.

The second set of cases was selected to allow us to examine the use of mechanisms historically, individually, and in combination at university research organizations. We chose a sample that matched two different types of research organizations (centers and departments), which we assumed would have different experiences with funding mechanisms. We defined centers as research organizations where research projects are coordinated into a coherent program in a broad field of interest at the university. Another defining characteristic of such organizations is core funding for equipment, facilities, and an administrative unit. We looked at centers that had received core funding from a government agency for at least 10 years and at departments that had received individual project awards in that same period of time.

Our sample of matched pairs cut across five fields of science. The final match of departments was made on the basis of location and the degrees to which the department matched the center in terms of types of research done and other factors, such as seniority of faculty members and coverage of distinctly different fields of science. The final sample is

comprised of 10 of the 25 universities that received the most federal research and development support and represents a mix of public and private institutions.

Table 1.2: Matched Pairs of Universities

Field of science	Center locations	Department locations
Mathematics	University of Wisconsin-Madison	University of Michigan
Space science	University of Chicago	University of Iowa
Artificial intelligence	Massachusetts Institute of Technology	University of Texas
Cell biology	Yale University	New York University
Plant sciences	Michigan State University	Cornell University

In selecting different fields of science, we addressed the Committee's interest in the impact of different styles of support or combinations of funding mechanisms on various fields.

Our data collection efforts involved the administration of a structured questionnaire to principal investigators at the various universities. We also asked universities to provide us with data on their use of different funding mechanisms from federal and nonfederal sources in 1970, 1975, and 1984-85.

The questionnaire was administered to assistant, associate, and full professors at the universities we visited. In all we interviewed 70 research faculty. Using this questionnaire, we gathered data on a variety of factors bearing on the perceived impact of federal individual project grant awards versus federal center awards in terms of coverage of resources, stability, types of research, and administrative burden. These factors are discussed in detail in chapter 3.

In all cases, data were cross tabulated by type of research organization (department or center) and by field of science (artificial intelligence, space science, mathematics, cell biology and plant science). In addition, a series of open-ended questions were asked to develop additional information about the perceived effects of funding on scientific research. These questions were designed to create small-scale case studies when the comments of all scientists in a particular center or department were aggregated.

Since the case study approach was used to address both objectives, an important caveat must be noted. Our study is not representative of all

fields of science, the totality of U.S. research universities, or all federal agencies or components of agencies.

We did not request agency comments because our work was not carried out at any agencies and we do not have any adverse comments about any agencies or organizations. However, we requested comments on portions of the report from the five universities cited in chapter 2 as having improved program quality. Those comments are incorporated in this report.

Chapter 2

Role of Funding Mechanisms in Improving the Quality of University Science

This chapter assesses the role of funding mechanisms in improving the perceived program quality of university science departments. In the 1960's federal agencies developed several funding mechanisms designed either to create new research expertise or to increase existing research expertise. These funding mechanisms had been discontinued by the early 1970's. In an effort to determine how selected university departments were able to improve their academic and research programs when the federal government had eliminated special financial assistance for research program improvement, we visited five universities that according to national surveys had successfully improved various departments over the past few years. (See objectives, scope, and methodology in chapter 1.) This chapter concentrates primarily on what funding and other strategies these universities used to improve the selected departments and how the departments were able to finance their program improvement initiatives.

We found that these departments financed program improvement plans by obtaining funds from federal grants, state government, industry, or university sources. With these funds the departments hired additional faculty, renovated research facilities, and purchased new equipment. These actions contributed to the quality of their research programs and enabled the departments to compete successfully for additional external grants and contracts. Although the departments used a variety of funding mechanisms, the individual project grant was the principal mechanism used by all the departments. Two departments received special science development grants from the National Science Foundation in the mid-1960's. Table 2.1 briefly summarizes the information we found concerning these funding mechanisms and program improvement strategies for these five departments. More detailed summaries follow the table.

Table 2.1: Characteristics of Departments With Improved Program Quality

University	Funding sources used to improve program	Federal research funds 1970	Federal research funds 1984	Percent Change	Key elements of improvement
Emory University, Microbiology and Immunology Department	University awarded $620,000 to department as seed money.	$ 140,466	$1,158,441	+725	Seed funding used to increase the number of tenured faculty members; new department chairman in 1979.
Georgia Institute of Technology, School of Chemical Engineering	Increase in support from industry, federal government, and foundations (industrial sponsors).	149,016	754,273	+406	1978 implementation of written plan for improvement of program. Plan focused on faculty recruitment and improving university relations with industry.
University of Alabama at Birmingham, Physiology and Biophysics Department	Seed money from state appropriations.	240,401	2,488,969	+935	New chairman in 1979; focus on hiring new faculty and increasing the number and quality of postdoctoral fellows.
University of Georgia, Botany Department	1967 NSF Science Development grant of $972,000 matched by an infusion of state funds and start-up funds from the university for new researchers. Individual research grant sustains program improvement; unrestricted income from an endowment fund.	405,695	1,673,874	+313	Support through a variety of funding mechanisms allowed expansion of space for faculty and student research and the addition of more faculty, equipment, graduate students, and postdoctoral fellows.
University of Texas at Austin, Physics Department	1966 NSF Science Development grant. Department strengthened by income from private endowment.	1,762,154	7,825,487	+344	Science Development Grant provided the opportunity to bring in high-quality junior and senior faculty with initial research support. University funding procedures enhanced acquisition of equipment, thereby improving program quality.

Emory University

The Chairman of the Microbiology and Immunology Department told us that the department began its greatest period of growth and improvement in 1979, when he was hired. The chairman described the department at that time as a modest, but decent one, which he believed could be expanded into a well-balanced, nationally recognized, high-quality department. The university's administration also wanted to improve the quality of the department and agreed to provide about $620,000 in "seed money" to increase the number of tenured faculty. Additional funds were provided to acquire more modern equipment for instructional and research purposes and to support additional graduate and postgraduate students. In addition, the university agreed to renovate space for the Microbiology and Immunology Department. According to

the department chairman, renovation costs were between $1.5 million and $1.75 million.

The chairman told us that the first priority for improving the department was to hire additional faculty members who were highly trained, prominent in their field, and who would aggressively seek external research funds through grants and contracts. When the chairman was hired in 1979, the department had eight faculty members. Today, the department has 11 faculty members, 5 of whom have been hired since the new chairman came on board. The current faculty has successfully increased the department's external funding from about $240,000 in 1979 to over $1.5 million in 1985, including about $1.4 million in federal funds. The department would like to increase its faculty to 16 or 18 members, but current space constraints have precluded further growth.

Acquiring additional equipment for research and instructional purposes was another high priority for improving the department. A 1978 appraisal of the department's laboratories concluded that existing equipment was not suitable for modern research approaches in microbiology. Since then, the department has purchased several new pieces of equipment.

According to the department chairman, applicants for predoctoral and postdoctoral training in the department have also increased in number and quality. In 1979 the Microbiology and Immunology Department had only 5 graduate students; today it has 24. The department has provided financial support for six of the predoctoral and postdoctoral students through a training grant from the National Institutes of Health (NIH). This grant, which began in July 1984, will provide a total of $499,640 over a 5-year period. The university has also increased its student fellowship support for this department from $32,500 in 1979 to a 1985 level of $65,700 per year.

NIH's Biomedical Research Support Grant provides additional funds on the basis of total amount of NIH grant dollars received by Emory. The university then shares these funds with various departments as the need arises, for example, to purchase expensive pieces of research equipment or provide interim support for faculty who are "between research grants." Research funds from the Multiple Sclerosis Society, the American Cancer Society, the Rockefeller Foundation, and the state of Georgia provided about $150,000 in 1984, or about 11 percent of the department's external research funds. Because Emory is a private university, it does not receive an appropriation from the state of Georgia.

Georgia Institute of Technology

School of Chemical Engineering officials told us that substantial improvements that were made in the quality of its faculty, graduate students, and educational program would not have been possible without a flexible university administration, a determined newly appointed Chemical Engineering director, and a supportive faculty. In a time of decreasing federal support for program improvement, Chemical Engineering developed a comprehensive written plan for improving the quality of its program. The essence of its plan was to achieve excellence by improving the quality of its faculty and graduate students. Improving relations with industry was also a priority.

Since 1978 the Chemical Engineering School has successfully attracted 11 new faculty members. The Director of Chemical Engineering, in reflecting on the improvement in quality of the school, cited a number of factors responsible for the successful recruitment of highly qualified new faculty. The factors he cited were

- a perception that the rapidly changing Georgia Tech Chemical Engineering program would be a good place to build or continue a career,
- the willingness of the Dean of Engineering to permit the school to recruit faculty at all ranks, and
- attractiveness as a place to work and live.

Faculty recruitment took priority over building the Chemical Engineering graduate enrollment. The department established an initial goal of four to five graduate students per faculty member and carried out extensive recruiting efforts to achieve that goal. In the summer of 1978 Chemical Engineering had only 12 graduate students; today, it has about 100.

In addition to improving the quality of faculty and graduate students, improving communications and relationships with industry was also a priority of the school director. He believed a good relationship with industry not only enhances educational opportunities for the students, but also increases industry's financial support for the program and contributes to the institution's stature. Activities aimed at improving the school's external relationships, including industry, during the past few years included

- establishing external advisory boards comprised of industrial and academic representatives interested in the program,
- publishing a new graduate program booklet containing specific program information and listing the research interests of individual faculty,

- issuing an annual alumni newsletter since 1979, and
- pursuing opportunities for interaction with industrial representatives.

The budget for Chemical Engineering has increased dramatically during the past 15 years. In 1970 the budget was approximately $582,000, but by 1984 the budget had grown to more than $3.5 million. The greatest budget increases have occurred since 1978, the year the new director was hired.

The increase in funds has come from several sources including the state of Georgia, the federal government, and industry. Because the Chemical Engineering School performs extensive research, a substantial part of its funds come from grants and contracts from industry and government agencies. In 1970 the state of Georgia supplied 68 percent of its funds, with the remaining 32 percent provided by industry, the federal government, and foundations. By 1984, however, the trend was away from state support, with only 50 percent of the school's funds coming from the state. The remaining 50 percent of the $3.5 million budget came from such external sources as industry, the federal government, and foundations (including industrial sponsors).

University of Alabama in Birmingham

Much of the Physiology and Biophysics Department's improvement, as reported in the 1982 "Assessment of Research Doctoral Programs in the United States," has occurred since 1979 when a new chairman was hired. According to the department chairman, the goal of the university's administration and departmental faculty was to accelerate the modest expansion that had taken place in previous years and generally to broaden the scope of research in the department. The department emphasized recruiting new faculty, consolidating the faculty into a single functional unit, purchasing new scientific and word processing equipment, restructuring the graduate program, and starting a series of departmental seminars featuring nationally recognized speakers from other universities. Of these stated goals, the chairman told us that the department has been most successful in improving the quality of its faculty and increasing the number and quality of its postdoctoral fellows. University officials attributed much of the department's improvement to a supportive and flexible university administration, a substantial increase in state funding, and the strong leadership of the new department chairman. A substantial increase in external funds also helped finance the program improvement initiatives.

The department chairman, in reflecting on the improvement in quality of the department, stated that his number one priority upon arriving was to build a strong research program. He believed this could be achieved by hiring the best possible researchers in their respective fields. Because of the university's willingness to hire faculty at all ranks and to pay highly competitive salaries to get them, the department has been successful in attracting 10 researchers since 1979. The chairman described these researchers as outstanding and as having international stature in their research field. These faculty members have aggressively sought external research funds that have helped to support the program improvement plans.

Funding for the department has grown dramatically over the last 10 years. In 1975, for example, the total departmental budget was only \$464,880. It had grown to \$1.7 million in 1980, but by 1985, the budget had increased to more than \$5.5 million. Department officials estimated that individual project grants make up at least 90 percent of awards in their department, and that the ability to compete successfully for external research money is one key to the program's success. Most of the increased funding has come from additional federal money for research, but substantial increases also occurred in funds from state appropriations and from nonfederal health agencies such as the American Heart Association, the American Cancer Society, and the Cystic Fibrosis Research Center. According to University officials, "seed money" from the university's state appropriation helped start the program improvement initiatives.

The Physiology and Biophysics Department Chairman told us that the department has also been successful in attracting outstanding graduate and postgraduate students. The most impressive growth has been in the number of postdoctoral fellows. In 1979, for instance, the department had only seven postdoctoral fellows. By 1984 that number had grown to 22, compared with a national average of 6 in a typical physiology department.

University of Georgia

University officials cited several factors that have been responsible for the improvement in the Botany Department.

- The university was committed to developing an excellent department.
- In 1967 the university received a \$6.0 million NSF Science Development Grant. The Botany Department's share of the grant was \$972,000. These funds and a commitment of funds from the state government enabled

the department to increase the faculty size from 15 to more than 20 and to purchase new equipment.

- The state provided over $3.4 million to build a new 157,000 square foot plant sciences building and allocated to the Botany Department 60,000 square feet for teaching and research facilities. The new space assisted in the recruitment of desired faculty specialists, and shared space promoted interdepartmental cooperation and communication. Part of the cost of this new building ($500,000) came from an NSF Science Development Grant.
- The university provides start-up funds for new researchers. Depending on the area of research, start-up costs range from $15,000 to $100,000 per researcher. For example, it costs about $100,000 to set up a plant molecular biologist with the necessary laboratory facilities and equipment to compete for external funding.
- Strong leadership from the university administration and Botany Department faculty promoted and encouraged research, which attracted external research funds. Federal research funds, for example, grew from $41,000 in 1965 to almost $1.7 million in 1984.
- In more recent years, income from a $1-million endowment fund, designated solely for the Botany Department, has also provided substantial unrestricted money that the department can use for special needs such as research equipment, student assistance, and travel.

Along with the improvement in faculty, research equipment and facilities, the department chairman believes the quality of graduate students has also improved. Currently, the Botany Department has about 50 graduate students, about 30 of whom receive teaching assistantships and 20 of whom have grant funds.

Although NSF's Science Development Grant served as a catalyst for program improvement, university officials believe that the individual research grant has been the major funding mechanism that has sustained the program improvement momentum. They believe a department needs start-up or "seed money" to attract high-quality faculty and provide necessary research space and equipment, but after that, the individual research grant is the mechanism for achieving the highest quality science research.

The Botany Department has experienced remarkable growth in funding. Federal funding has grown from $41,000 in 1965, to $405,000 in 1970 (includes part of the NSF Science Development Grant) to almost $1.7 million in 1984. Total department funds from the state and federal governments, industry and foundations, and endowment income grew from

$1.7 million in 1980 to more than $3.0 million in 1984. Most of this growth has been in federal research funds through individual research grants.

University of Texas at Austin

According to the Physics Department Chairman, since receiving an NSF Science Development Grant in 1966, the department has made progress in improving the quality and number of faculty and graduate students and in improving its overall research program. Funds provided by the grant were used for (1) additional faculty, (2) initiation of new research activities, (3) establishment of a Faculty Associate Program whereby recent doctoral recipients were brought to campus for 2-year periods of introduction to teaching and research, and (4) initiation of a program of curriculum development. University administrators stated that a major positive effect of the NSF Science Development Grant was the opportunity it provided for bringing in high-quality junior and senior faculty with initial research support at a time when few universities could provide such funding. The Physics Department had 25 faculty members in 1965 but, with this grant, the faculty grew to 40 by 1968. The department has continued to grow and currently has a faculty of 65, including 2 Nobel laureates and 5 members of the National Academy of Sciences.

In addition to improving the quality of the faculty, the quality and number of the graduate students has also improved. According to present and former department chairmen, graduate enrollment has increased from 100 in 1965 to over 250 in 1985. In addition, postdoctoral fellows have increased from none in 1965 to over 100 in 1985.

Expenditures for the Physics Department have increased from $1.9 million in 1970 to $10.8 million in 1984. Income from private endowment has greatly strengthened the department financially. At the time of our visit, the department had six endowed chairs at $1 million each, six endowed professorships at $100,000 each, and one lectureship. In addition, the University of Texas System has an endowment valued at about $2 billion. Income from the endowment is about $150 million per year with two-thirds going to the University of Texas System and one-third going to the Texas A&M System. With this endowment income, the universities pay off bond obligations, finance construction projects, and provide funds for overall program improvement at the schools.

One important feature of the University of Texas at Austin's funding procedures is that the university matches federal grant funds designated for equipment. For example, if a researcher in the Physics Department receives a $100,000 federal grant that includes $20,000 for equipment, the university will provide matching funds for the equipment part of the grant. A university official told us this matching procedure is a very effective method of improving the department's research program.

As mentioned earlier, the Physics Department Chairman told us that the NSF Science Development Grant awarded in 1966 was a major factor in the overall improvement of Texas' Physics Department. However, when we discussed with university officials the success of this grant, they cautioned us about the widespread use of this type of funding mechanism. School officials told us that the success of development grants depends greatly on proper planning for the use of the funds. For example, if the funds are used to increase the number of faculty in the department, the university must be able to absorb these faculty costs whenever the grant funds are discontinued. Otherwise, the university might have to reduce its faculty and the school would be back where it was in the beginning, before the grant funds.

Summary

In the development of productive university research organizations, funding mechanisms play different roles at different stages. The common element that was reported to us in improvement at the universities we visited was an explicit commitment from the university to improve its program and to do so through increases in internal and external funding and personnel changes.

Seed funding from either government or private sources was reportedly a prerequisite to program improvement in all of the departments we visited. Two of the five departments we visited received substantial NSF Science Development grants in the late 1960's. University officials at both schools agreed that the availability of these federal grants was a major factor in their program improvement strategy and enabled each department to attract excellent researchers, renovate research space, and purchase critical equipment. Although the other three departments did not receive science development grants, they were able to obtain financial support from the university, state government, and industry.

After the investment of seed money in the departments we visited, faculty members competed successfully in their fields, and the primary

source of support became the individual project mechanism. These moneys, along with supplemental support from state government, endowments, industry, or university funds, can generally sustain the quality program, at least in the short run. In the departments we visited, the universities' commitment to absorb the increased faculty costs when the science development grant or other seed money ended, helped sustain the high-quality programs and allowed the departments time to secure adequate external funding to make them predominantly self-supporting. The seed money was thus "leveraged" to obtain a broader base of support.

Chapter 3

Role of Funding Mechanisms in the Performance of Research

The House Science and Technology Committee requested that we assess the relative merit of different funding mechanisms in terms of their effects on the productivity and performance of research. While the previous chapter focused on factors affecting the improvement of program quality, this chapter examines the impact of two different funding mechanisms on the performance of research. We compared five departments that rely primarily on the funding mechanism of individual project grants with five centers that rely primarily on the funding mechanism of center support. For each department or center, we examined four key factors that had the potential to affect the performance of research—coverage of research requirements, stability of financial and resource support, the influence of funding mechanisms on the flexibility to pursue new and different categories of research, and administrative burden. (See objectives, scope, and methodology in chapter 1.) While our primary focus was to identify the impact of two funding mechanisms on these key factors influencing the performance of research, the case study approach also provided insights into other influences on the performance of research.

We found that particular funding mechanisms, such as individual project awards, do not by themselves have consistent advantages or disadvantages for the performance of university research. With few exceptions, no clear-cut differences emerged between the experience of center- and department-based scientists with federal support. The nature of the funding and the extent of resource coverage depend upon many factors, such as differences between agencies, university policies, and varying resource needs. We also found that:

- Distinctions between individual project awards and center funding are blurred by scientists' strategies to increase their ability to perform research, for example, grant applications to multiple sources.
- Certain characteristics of the individual project award mechanism result in some problems, for example, discontinuous funding for graduate students.
- Issues specific to each field of science, as well as certain characteristics of funding mechanisms, can impede the performance of research.

The remainder of this chapter highlights findings from our analysis of the impact of funding mechanisms and other influences on four key factors with the potential to affect research performance.

Appendix I summarizes the responses of all scientists to selected questions.

Coverage of Resource Requirements

The performance of research requires continued coverage of resource requirements. Scientists need trained technicians, equipment, and space to conduct laboratory experiments and other research. Fields of science differ in their resource requirements, depending on the stage of each field's development and its technological requirements. For example, mathematicians working on "pure" theory may work in isolation with few assistants and little or no equipment. In contrast, cell biologists told us they may utilize a number of lab assistants, while space scientists told us they may need large amounts of capital for equipment. In such labor- or capital-intensive fields, interruptions or delays in access to resources can slow research progress or force dissolution of established research teams and laboratories.

We found that while certain funding mechanisms provided more continuous access to resources, the design of specific mechanisms seemed to have less effect on the performance of research than the total volume of funding available for different fields of science and fluctuations in that funding. The responses of scientists regarding their ability to acquire needed resources clustered more by fields of science than by experience with particular funding mechanisms.

The lack of variation in responses from scientists receiving support from center or individual project awards to cover resource requirements might be accounted for by a number of other issues mentioned by the scientists we interviewed. The coverage of resource requirements reflects interactions between an agency's decisions resulting from its review process and policies and an individual scientist's definition of resource needs for a specific project in a given field of science. Resource coverage may be influenced by

- the degree of variation among types of support, even within a single funding mechanism category;
- differences in agency review processes;
- agency policy decisions, such as use of funds to cover equipment or graduate education;
- the extent to which universities supplement resources;
- the types of research undertaken, as well as the scale of research efforts;
- individual scientists' perceptions of the extent to which their funding requests will be approved; and
- scientists' informal knowledge of what criteria govern decisions made by agency officials or groups of scientific reviewers.

These interactions can be better understood in the context of three resource coverage areas we examined: facilities, equipment, and human resources.

Facilities and Equipment

Experience with individual project or center awards did not appear to be the significant factor in affecting scientists' responses to questions concerning adequacy of equipment and facilities. Instead, perceptions of problems in these areas differed by field of science.

Overall, 28 of 36 researchers who had been in the federal award system since 1970 said that the quality of facilities for their research had increased or stayed the same. Scientists in two fields—plant sciences and artificial intelligence—did not report decreases in quality of facilities since 1970. Scientists reporting decreases were in cell biology, mathematics, and space science.

Table 3.1: Facilities

		Figures in percentage			
		Increased	Same	Decreased	
Has the quality of facilities changed since 1970?	Center	42.9	21.4	35.7	n=14*
	Department	54.5	31.8	13.6	n=22

*"n" here and through the text indicates number of scientists who responded to the question.

Differences among fields of science were also seen in equipment coverage. Although scientists in all fields, with the exception of mathematicians, expressed concern over equipment, space scientists showed the most concern (8 of 11). They told us that much of their equipment is 20 years old and is maintained periodically by scientists and technicians. In addition, as table 3.2 shows, over half of the scientists stated that needed equipment is difficult to obtain. There are no clear-cut differences in the experiences of center and department scientists in the ease or difficulty in obtaining equipment.

Table 3.2: Equipment

		Figures in percentage		
		Agreed	Disagreed	
The equipment I need is very difficult to obtain under current programs.	Center	54.5	45.5	n=22
	Department	53.3	46.7	n=30

Human Resources

The funding mechanisms we looked at were not the most significant factor influencing responses by scientists to our questions about coverage of such human resources as technicians and graduate students. Problems with funding for technicians cut across a number of fields of science—cell biology, plant science, artificial intelligence, and space science. Scientists attributed problems with hiring and retaining technicians to factors other than funding mechanisms, such as industrial competition and current salary structures for technicians at different universities.

Table 3.3 indicates that both center and department scientists view this as a problem. Center scientists felt more difficulties with the availability of technicians, although both center and department scientists reported difficulties in supporting technicians.

Table 3.3: Technicians

		Figures in percentage			
		Increased	Same	Decreased	
Has the availability of technicians changed since 1970?	Center	10.0	30.0	60.0	n=10
	Department	18.2	54.5	27.3	n=11
			Agreed	Disagreed	
It is difficult to support technicians needed.	Center		76.2	23.8	n=21
	Department		86.4	13.6	n=22

Problems cited by scientists relating to funding coverage for graduate students touched on a number of interrelated issues concerning university goals and funding mechanisms available for supporting these goals. We found variations in the types of personnel supported by university research groups. For example, some centers have a clearly defined training function, while others support research and not graduate education. In addition, we found that some problems associated with support for graduate students could be traced to the type of funding mechanism used. Scientists across all fields (58 of 66) agreed that project support should not be used to support graduate students as is the current practice. The negative effects they cited included the disruption caused for graduate students by the loss of support from individual project awards. They suggested the establishment of separate mechanisms for graduate student support.

Stability of Financial and Resource Support

A relatively stable resource and financial environment is generally considered beneficial for the conduct of science. Particularly in resource-intensive areas and ones where teams of researchers must be assembled, the predictability of continued funding is important. The stability of support depends not only on the continuity of funding, but also on its duration through a project's cycle. To determine the impact of funding mechanisms and other factors on the stability of support, we examined: the cyclical nature of support, lengthy gaps between periods of funding, and appropriateness of award duration for the research being performed.

The Cyclical Nature of Support

We found that while center support provided more continuous access to resources, the total volume of funding available for different fields of science and fluctuations in that funding seemed to have more of an effect on the performance of research than the design of specific mechanisms. Both center and department scientists we surveyed told us they have had their federal funding cut (table 3.4). Scientists recognized the cyclical nature of federal support for different topics of research. Scientists also recognized the increased opportunities to compete for private support in areas of commercial potential and industry interest, such as artificial intelligence and plant biology in agriculture.

Table 3.4: Funding Cuts

		Figures in Percentage		
		Yes	No	
Have you ever had your project funding cut?	Center	77.4	22.6	n=31
	Department	83.3	16.7	n=36

Scientists in fields of shifting program priorities can also be affected by the cyclical nature of support. For example, NSF's attempt to ensure stability at the field of science level in mathematics by dividing available funds for the mathematics subfields, such as complex analysis, resulted in destabilizing research environments for certain other subfields and individuals. This example shows that the effects of funding mechanisms on university research cannot be assessed without consideration of contextual factors such as agency policies.

The influence of factors other than funding mechanisms on the stability of the support can be seen in fields of science dependent on NIH funding. The Office of Management and Budget proposed cutting the number of NIH awards from 6,529 in fiscal year 1985 to 5,000 new and continuing awards in fiscal year 1986 and further to use the savings from that

reduction to spread the available funds by distributing the awards over 2 or more years instead of 1 year. Scientists in cell biology, one of the fields supported by NIH, told us they were concerned with the politicization of federal funding for research (e.g., we heard comments such as "non-scientific events at the federal level," "arbitrary OMB decisions," and that fluctuations "depend on the Administration"). Their perceptions of instability are indicated by the contrast between their success in obtaining funding and an increased sense of unpredictability (table 3.5).

Table 3.5: Changes Over the Last 15 Years in Areas Affecting Research Performance

		Figures in Percentage			
		Increased	Same	Decreased	
How has the predictability of obtaining federal project funding changed?	Center	23.1	15.4	61.5	n=13
	Department	27.3	27.3	45.5	n=22
How has your success rate in funding changed?	Center	10.0	80.0	10.0	n=10
	Department	11.1	66.7	22.2	n=18

Funding Gaps

We found that the type of funding mechanism used had a more significant impact in the area of funding gaps than in other areas related to stability. For departmental scientists who received individual project awards, rather than center funding, funding gaps sometimes translated into ending support that broke up research teams and caused the loss of trained professional technicians. Scientists noted that the social and economic costs of funding gaps (human suffering, retooling, increased time expended by scientists in the day-to-day operations of the lab) were an intangible cost in the performance of research.

In contrast, we found that the center mechanism provided a measure of flexibility that enhanced the stability of the research environment for those scientists who received center support. Scientists cited the informal sharing of resources possible under center funding as one contributing factor to stability of funding. Center funding provides some seed money to start research that would otherwise be unfunded and bridges periods when noncenter funds are terminated. Finally, it can provide for more continuous support of professional technicians. Funding gaps in the centers were seen as delays in funding, rather than as an end to support.

Although center support provided more stability in funding, we found that some department scientists had developed strategies that seemed to compensate for funding gaps. To prevent an abrupt stop to their

research, scientists will apply to multiple sponsors in order to guarantee the continuity of their work. When one project ends, the researcher is still receiving support from other sources. A second device is the practice of working as a co-investigator on someone else's award. To meet equipment needs, scientists in one department we visited collaborated and were able to pool resources from various project awards in order to establish equipment for common use.

Table 3.6: Funding Gaps

		Figures in Percentage		
		Yes	No	
Have funding gaps been a problem?	Center	27.6	72.4	n=29
	Department	50.0	50.0	n=34

Award Duration

Scientists receiving both types of mechanisms expressed concern about award duration (table 3.7). However, scientists in most of the centers we studied commented that they had a longer term commitment under the center mechanism than scientists who received individual project awards. Award duration affects stability because award periods do not always match the actual time needed to perform research, which can vary even within a field. For example, one scientist told us that biochemistry projects take considerably less time to complete than genetic manipulation experiments in agriculture, where scientists must allow a complete regeneration of crops before testing can take place. Scientists also suggested that for many fields, shorter duration awards (less than 2 years) did not recognize start-up time as a legitimate facet of research and thus did not permit the following of coherent research strategies. Finally, scientists recognized the difference between the long-term way in which they perceive research (scientists conceptualized their work as life long, or in terms like "a 50-year project") and the relatively short-term way in which funding agencies perceive research (in 3-to 5-year increments).

Table 3.7: Experience With Federal Awards

		Figures in Percentage		
		Agreed	Disagreed	
Award periods are too short to finish a project within one award cycle.	Center	59.3	40.7	n=27
	Department	61.8	38.2	n=34
There's not enough time to complete scholarly articles during the project award period.	Center	45.2	54.8	n=31
	Department	54.5	45.5	n=33

Types of Research

Some differences in the types of research supported emerged between the two mechanisms studied. One criticism of the individual project award review system is that it does not adequately support innovative, high-risk research. A task force of the National Science Foundation Advisory Council identified the following three classes of innovative, high-risk proposals: research that challenges currently accepted scientific hypotheses; interdisciplinary proposals or research that transfers knowledge from one scientific field to another; and research that is at the edge of technical feasibility. To determine which mechanisms (centers or individual project awards) more often support innovative, high-risk, and interdisciplinary research, we asked scientists a series of questions about their research.

We found that more scientists in centers are likely to perform the types of research defined as innovative, high risk, or interdisciplinary. More center than departmental scientists:

- performed research bridging two or more fields (30 of 32 center scientists versus 21 of 36 departmental scientists);
- proposed research into new areas (25 of 32 center scientists versus 14 of 33 departmental scientists); and
- proposed work with industrial applications (9 of 32 center scientists versus 3 of 33 departmental scientists).

Although innovative, high-risk, and interdisciplinary research tended to be performed by scientists in centers, in certain cases the field of science, not the affiliation with a center or department, seemed to influence the types of research performed. For example, all plant scientists in the center and department (11 of 11) described their research as interdisciplinary, bridging two or more fields. Differences were not clear cut between scientists who proposed new technical processes with support from the center or individual project awards. Few mathematicians had proposed new technical processes (3 of 20) or proposed research into new areas (7 of 13). In contrast, almost all plant scientists (10 of 11) and scientists in artificial intelligence (8 of 9) had proposed research in new areas.

Administrative Burden

One aspect of the current reliance on the individual project award system that has been criticized by scientists is the time and expense of preparing and administering a large volume of applications. Time spent by scientists in preparing and reviewing research proposals is seen as

resulting in a decline of research productivity. Discussion has also suggested a need to streamline procedures for administering grants and contracts, without reference to the particular funding mechanism involved.

The time commitment by scientists required to participate in the federal funding system can be divided into two categories: preaward and postaward. This time encompasses not only proposal applications, but also responses to sponsoring agencies' requests for proposal review, participation in technical monitoring, and the preparation of status and final work reports.

We examined the relative amount of time spent in award-related activities by scientists receiving center support and those departmental scientists receiving support from individual project awards. We were also interested in whether scientists perceived differences in administrative burden between sponsors. We also asked university administrators to comment on these issues.

We found that, for the scientists we interviewed, the amount of time spent applying for awards, responding to award requirements, and reviewing proposals varied not by type of mechanism but more by the field of science and the requirements of the dominant agency sponsoring research in each field. We also found that no single issue emerged among these 70 scientists regarding the presence of administrative burden. Scientists' perceptions of difficulties in this area can be shaped by a number of factors: whether individuals or groups submit multiple applications in order to obtain federal awards, the number of researchers in relationship to available funding, and changes in agency requirements. We found that scientists at the schools we visited tended to cite a number of problems when specifically asked about administrative burden, ranging from the time spent in responding to regulations imposed by different governmental bodies to time and effort reporting.

Table 3.8: Average Time Spent by Scientists in Award-Related Activities

	Writing applications weeks/year	Proposal review days/ year	Status reports days/year	Technical monitoring days/year	Noncompetitive renewal days/ year
FIELD OF SCIENCE					
Plant science	5.6 n=10	18.5 n=11	6.3 n=11	3.6 n=10	3.7 n=9
Cell biology	4.7 n=12	15.5 n=10	5.4 n=14	3.1 n=14	1.1 n=14
Mathematics	2.0 n=20	5.9 n=20	2.6 n=18	.8 n=16	1.9 n=14
Space science	3.5 n=11	7.7 n=12	4.1 n=11	1.2 n=11	3.5 n=11
Artificial intelligence	3.9 n=10	9.7 n=10	6.6 n=9	6.4 n=9	1.9 n=9
All scientists	3.6 n=63	10.6 n=63	4.7 n=63	2.7 n=60	2.3 n=57

Table 3.8 lists differences among fields for the 10 schools we visited in the amount of time spent in activities. Differences result from variation in agency requirements for funding research rather than from the type of mechanism employed. The major distinctions among fields seemed to be in the area of preaward and postaward requirements. Scientists receiving funding from the Department of Defense, the National Aeronautics and Space Administration, and the Department of Energy (agencies that make decisions internally or through combined internal and external review) might spend less time on proposal review, one example of a preaward requirement, than scientists supported by NSF and NIH. NSF and NIH use only one form of decision making, peer review, a process designed to have groups of scientists to review the merits of work proposed by colleagues in various specialties. In contrast, researchers in artificial intelligence spent more time responding to the requirements of technical monitors, a postaward requirement common in research funded by the Department of Defense. Three scientists in artificial intelligence, a field that receives support from both civilian and defense agencies, perceived NSF to be the most burdensome in preaward requirements and least demanding in postaward requirements compared to defense agencies.

While there were no clear-cut differences overall in the administrative requirements, we found that some centers are designed in such a way as to insulate staff from the burden of administrative tasks. For example,

at one university the center director had a small core staff to handle the writing of proposals and other award-related tasks.

One postaward issue we specifically addressed concerned the ease or difficulty in shifting funds between expenditure categories (table 3.9). We asked researchers whether they found it difficult to shift funds between categories. We wanted to know whether they had the flexibility to shift resources in the event of unexpected events such as a change in the direction of their research. This did not seem to be a clear-cut issue for center investigators, who split on their responses to this question. In contrast, more department scientists (25 of 34) found it easier to shift funds. Certain restrictions seem to lead some researchers to resort to other sources of funding rather than attempt to acquire approval for such expenses as travel or equipment. However, several researchers praised NIH and NSF, agencies that have decentralized administrative responsibility for overseeing shifts in expenditures to the university level. We also found examples of unique forms of the individual project award that are flexible in character, such as general research contracts from the National Aeronautics and Space Administration and the Office of Naval Research.

General research contracts have broad objectives and provide the principal investigator with considerable discretion in how the funds are used. Among other uses of these contracts, the principal investigator can support young investigators who have not established a performance record or technicians and graduate students during funding gaps.

Table 3.9: Shifting Funds

		Figures in Percentage		
		Agreed	Disagreed	
It is difficult to shift funds between expenditure categories.	Center	50.0	50.0	n=22
	Department	26.5	73.5	n=34

For university administrators, three factors affect the amount of time spent in administering federal research awards. Administrative time can be increased by institutional policies for review, differences in the process of negotiating and administering contracts with different sponsors, and difficulties with specific legal instruments rather than funding mechanisms.

Summary

Our case studies of the role of different funding mechanisms in enhancing or inhibiting research performance show that particular

funding mechanisms we looked at do not always have consistent advantages or disadvantages in the performance of research. Performance of research can be affected by any of the following factors: resource coverage, stability, the flexibility to pursue new research ideas, and administrative burden. For these factors, we found issues that were either funding mechanism-related, field of science-related, or cut across funding mechanisms and fields of science.

In looking at the issues that relate to specific funding mechanisms, the center grants we examined were somewhat more likely to provide more continuous access to resources; to afford a greater degree of stability for the performance of research; and to enhance the performance of innovative, high-risk, or interdisciplinary research.

Field of science-related issues included the following: the cyclical nature of support for the field, changes in agency relationships, and the unique needs of subfields. The cyclical nature of support for different fields seemed to explain differences in resource coverage between fields. Differences among fields of science were seen in coverage of resources—facilities and equipment. For example, scientists in organizations receiving a relatively rapid increase in volume of funding, such as artificial intelligence and plant biology, said that the quality of facilities for their research had increased or stayed the same. Space scientists, working in a field with stable or decreasing funding, showed more concern over the condition of their facilities and equipment. Cell biology is a field of science that illustrates the effects of a change in agency relationships. In this field, which is primarily supported by NIH, scientists we interviewed described the destabilizing of their research environment caused by executive branch decisions to change the number of awards made by NIH for individual project support. The unique needs of subfields can also affect scientists' experience with funding mechanisms. For example, the time needed to perform research can vary even within a field as in the case of plant biology in which it may take several years for a new crop to grow and be tested.

Issues that cut across mechanisms and fields of science include the current problem of finding and keeping technicians. Similarly, perceptions of administrative burden seemed influenced by factors other than mechanisms and characteristics of a field of science. Problems were attributed to a range of factors, including university procurement policies and state and municipal regulations.

Summary of All Scientists' Responses to Selected Questions

Figures in Percentage

Stability of Financial and Resource Support	
Has the success rate in funding of federal proposals over the last 15 years changed? (n=28)	
Increased	17.9
Same	71.4
Decreased	10.7
Award periods are too short to finish a project within one award cycle. (n=61)	
Agreed	60.7
Disagreed	39.3
There is not enough time to complete scholarly articles during the project award period. (n=64)	
Agreed	50.0
Disagreed	50.0
Have you had problems because of gaps in your funding? (n=63)	
Yes	39.7
No	60.3
Has the predictability of obtaining federal project funding changed over the last 15 years? (n=35)	
Increased	25.7
Same	22.9
Decreased	51.4
Have you ever had your project funding cut? (n=67)	
Yes	80.6
No	19.4
Coverage of Resource Requirements	
Has the quality of facilities changed since 1970? (n=36)	
Increased	22.2
Same	27.8
Decreased	50.0
The equipment I need is very difficult to obtain under current federal award program. (n=52)	
Agreed	53.8
Disagreed	46.1
Has the availability of technicians changed since 1970? (n=21)	
Increased	14.3
Same	42.9
Decreased	42.9
It is difficult to support technicians needed. (n=43)	
Agreed	81.4
Disagreed	18.6
Types of Research	
Some projects are not funded because they don't fit conventional areas favored by reviewers. (n= 55)	
Agreed	41.8
Disagreed	58.2
Administrative Burden	
It is difficult to shift funds between expenditure categories. (n=56)	
Agreed	35.7
Disagreed	64.3

"n" indicates the number of scientists who responded to the question.

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